Results in Physics 6 (2016) 447–448

Contents lists available at ScienceDirect

Results in Physics

journal homepage: www.journals.elsevier.com/results-in-physics

Microarticle

Emission properties of biomimetic composites for dentistry

P.V. Seredin [a,*], D.L. Goloshchapov [a], V.M. Kashkarov [a], Yu.A. Ippolitov [b], T. Prutskij [c]

[a] Department of Solid State Physics and Nanostructures, Voronezh State University, Voronezh, Russia
[b] Department of Pediatric Dentistry with Orthodontia, Voronezh State Medical University, Voronezh, Russia
[c] Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla, Puebla, Mexico

ARTICLE INFO

Article history:
Received 7 July 2016
Accepted 2 August 2016
Available online 8 August 2016

Keywords:
Biocomposites
IR-spectroscopy
Optical and emission properties
Hydroxyapatite
Human tooth tissues

ABSTRACT

Biocomposites based on carbonate-substituted hydroxyapatite synthesized from the biological source of calcium (Goloshchapov et al., 2013) and organic primer on the basis of amino acids found in the enamel tubules of teeth, namely, arginine, histidine, lysine and hyaluronic acid were obtained and studied in this work. Incorporation of organic primer into biocomposite formulation allowed us to obtain the emission characteristics (luminescence) that were identical to those inherent to the native tissues of the human tooth (enamel and dentine).

Introduction

Optical and emission properties of the human hard dental tissues (enamel and dentin) in the infrared, visible and ultraviolet ranges are closely related to their fine structure. The latter is determined by the intra-lattice substitutions as well as by a molecular and local atomic environment in their mineral and organic components [2–4]. As it has already been shown [3], the presence of various organic complexes in the composition of the hard dental tissue has a rather strong effect on its optical properties in the range from 250 to 700 nm. Note that the part of organic compounds is of no more than ~5% for the enamel and is of ~40% for the dentin relative to the mineral component – calcium hydroxyapatite (HAP). While solving the problems of contemporary preventive dentistry connected with the restoration and repair of the native hard dental tissue it is very important to attain specific optical properties of the synthetic materials (brilliance, color, transparency and luminescence) that are identical to the native dental tissue. This can be achieved due to a controllable incorporation of organic compounds into the formulation of a biocomposite on the basis of HAP [2,4–6]. However, such kinds of systems are not yet capable of reproducing structural, morphological and optical characteristics of the hard dental tissues at the same time with a satisfactory quality [2,4]. Therefore, the aim of our work was to produce the materials – biomimetic composites corresponding to the native tissues of the human tooth in their composition and basic parameters.

Methods

Biomimetic composites were synthesized with the use of nanocrystalline carbonate-substituted hydroxyapatite (CHA) corresponding by its structural and morphological properties to the apatite of dental enamel using the suggested technique [1,7,8]. Organic component of biocomposite (primer) involved amino acids found within the enamel tubules of teeth. Arginine, histidine, lysine and hyaluronic acid were mixed on the basis of isotonic solution with nanocrystalline CHA in the ratios of 5/95, 25/75, 40/60, reproducing to some extent the composition of enamel end dentin of the human tooth. The analysis of the molecular structure and composition of the obtained materials was performed using IR-spectroscopy with the use of IR Fourier spectrometer Vertex-70 (Bruker, Germany) and the attachment for the attenuated internal total reflection PLATINUM ATR. The spectra were surveyed within the range of 4000 – 500 cm^{-1}. Photoluminescence spectroscopy technique was applied to compare the organic-mineral composition and stoichiometry of biocomposites with the native human dental tissue. Luminescence spectra were obtained at the room temperature from the samples surface according to the technique described in [9] with the use of the unit supplied with TRIAX550 monochromator and CCD detector. The laser output power was of ~30 mW.

Results and conclusions

IR-spectra of synthesized biocomposites with the ratio of organic and inorganic components of 5/95 (curve 1), 25/75 (curve 2), 40/60 (curve 3) are presented in Fig. 1a–c. According to [4],

* Corresponding author.
E-mail address: paul@phys.vsu.ru (P.V. Seredin).

http://dx.doi.org/10.1016/j.rinp.2016.08.003
2211-3797/

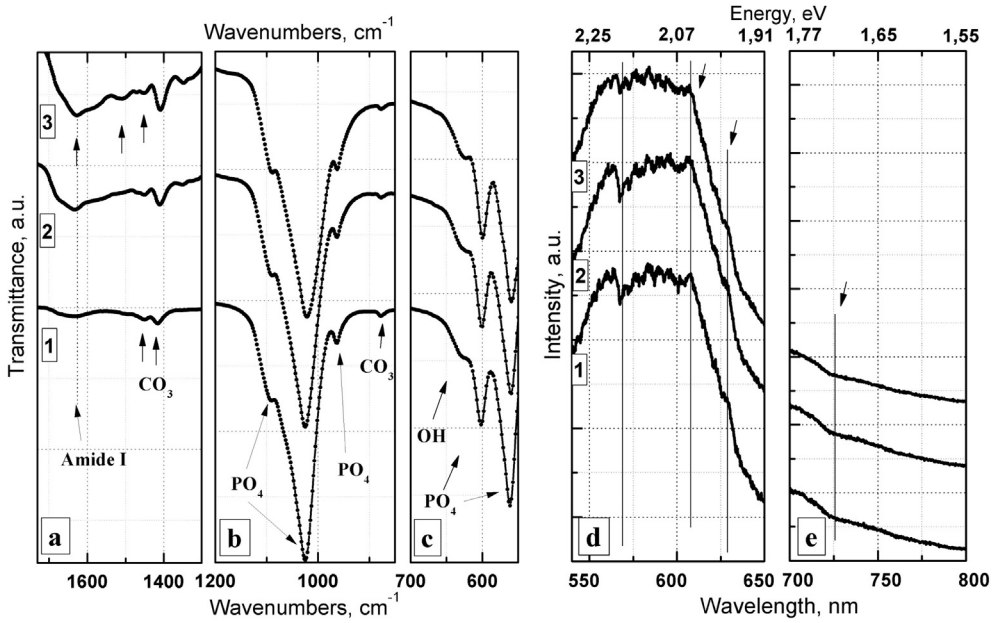

Fig. 1. IR-spectra (left) and luminescence spectra (right) of synthesized biocomposites: 1 – biocomposite with 5/95 formulation, 2 – biocomposite with 25/75 formulation, 3 – biocomposite with 40/60 formulation.

the presence of the characteristic set of modes in the ranges of 1350–1650, 900 –1200 and 550–800 cm^{-1}, in IR-spectra of the investigated samples as well as the ratio of their relative intensities makes it possible to conclude that the synthesized biocomposites reproduce mineral-organic composition of enamel and dentin in the human teeth. Fig. 1d and e represents the results of luminescence spectroscopy for the synthesized biomimetic materials with the organic-mineral ratio in the formulation of 5/95 (curve 1), 25/75 (curve 2), 40/60 (curve 3). The analysis of the experimental data on luminescence and their comparison with those presented in [2,3] indicates that the shape of spectra and energy position of the peaks (specific features) entirely correspond to the similar spectral (energy) characteristics of the native enamel and dentin in the human teeth. The change of the relative intensity of the features (peaks) in the luminescence spectra of biocomposites (Fig. 1d) is determined by the ratio of organic primer and mineral component in the formulation, i.e. by the biocomposite composition. This result is in very good agreement with the data on IR-spectroscopy concerned with the change of intensity of the phosphate and amide groups revealed in the IR-spectra (Fig. 1a and b). The observed features in the spectra of luminescence in the intact tissues and biocomposites modeling of these tissues can be used for the development of the diagnostics methods intended for the determination of the extent of demineralization arising under carious lesion of the hard dental tissues as well as for the assessment of the teeth state as a whole.

Funding

This work was supported by the Grant of Russian Science Foundation, Grant No. 16-15-00003.

References

[1] Goloshchapov DL, Kashkarov VM, Rumyantseva NA, Seredin PV, Lenshin AS, Agapov BL, et al. Synthesis of nanocrystalline hydroxyapatite by precipitation using hen's eggshell. Ceram Int 2013;39:4539–49. http://dx.doi.org/10.1016/j.ceramint.2012.11.050.

[2] Jablonski T, Takahashi MK, Brum RT, Rached RN, Souza EM. Comparative study of the fluorescence intensity of dental composites and human teeth submitted to artificial aging. Gen Dent 2014;62(1):37–41.

[3] Bachmann L, Zezell DM, Ribeiro A da C, Gomes L, Ito AS. Fluorescence spectroscopy of biological tissues—a review. Appl Spectrosc Rev 2006;41:575–90. http://dx.doi.org/10.1080/05704920600929498.

[4] Hędzelek W, Marcinkowska A, Domka L, Wachowiak R. Infrared spectroscopic identification of chosen dental materials and natural teeth. Acta Phys Pol A 2008;114:471–84. http://dx.doi.org/10.12693/APhysPolA.114.471.

[5] Sowmya S, Bumgardener JD, Chennazhi KP, Nair SV, Jayakumar R. Role of nanostructured biopolymers and bioceramics in enamel, dentin and periodontal tissue regeneration. Prog Polym Sci 2013;38:1748–72. http://dx.doi.org/10.1016/j.progpolymsci.2013.05.005.

[6] Sobczak-Kupiec Agnieszka, Malina Dagmara, Kijkowska Regina, Wzorek Zbignie. Comparative study of hydroxyapatite prepared by the authors with selected commercially available ceramics. Dig J Nanomater Biostruct 2012;7:385–91.

[7] Domashevskaya EP, Al-Zubadi AA, Goloshchapov DL, Rumyantseva NA, Seredin PV. Structure and composition of metal-substituted calcium-deficient hydroxyapatite. J Surf Invest X-Ray Synchrotron Neutron Tech 2014;8:1128–36. http://dx.doi.org/10.1134/S1027451014060032.

[8] Kashkarov VM, Goloshchapov DL, Rumyantseva AN, Seredin PV, Domashevskaya EP, Spivakova IA, et al. X-ray diffraction and IR spectroscopy investigation of synthesized and biogenic nanocrystalline hydroxyapatite. J Surf Invest X-Ray Synchrotron Neutron Tech 2011;5:1162–7. http://dx.doi.org/10.1134/S1027451011120068.

[9] Seredin P, Goloshchapov D, Prutskij T, Ippolitov Y. Phase transformations in a human tooth tissue at the initial stage of caries. PLoS ONE 2015;10:1–11. http://dx.doi.org/10.1371/journal.pone.0124008.